WRIA 5 – Stillaguamish Instream Flow Project

Task 2 – Review and summarize reports identified by the Agency.

"Four documents identified by the Agency will be reviewed and summarized to provide basin-specific information to support the development of targeted, ecologically beneficial instream flows. The review will focus on the physical habitat needs of fish during specific life stages, fish distribution, habitat use and timing in WRIA 5, as well as the hydrology of the Stillaguamish basin. The documents to be reviewed include the following:"

Beamer, E.M., and G.R. Pess. 1999. The effects of flooding on Chinook (Oncorhynchus tshawytscha) spawning success in two Puget Sound River Basins. Proceedings from Watershed Management to Protect Declining Species. American Water Resources Association Annual Water Resources Conference. December 6-9, 1999. Seattle, WA. pp. 67-70.

Pess, G.R., B.D. Collins, M.M. Pollock, T.J. Beechie, A. Haas, and S. Grigsby. 2000. Historic and Current Factors that limit Coho Salmon (Oncorhynchus kisutch) Production in the Stillaguamish River Basin, Washington State: Implications for Salmonid Habitat Protection and Restoration. A report prepared for Snohomish County Department of Public Works and the Stillaguamish Tribe of Indians. 46 pp.

Collins, B.D. 1997. Effects of land use on the Stillaguamish River, Washington ~1870 to ~1990: Implications for salmonid habitat and water quality and their restoration. Report to the Stillaguamish Tribe of Indians. 77 pages.

Washington State Conservation Commission. 1999. Salmon habitat limiting factors final report. Water Resource Inventory Area 5, Stillaguamish Watershed. 83 pages.

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Summary Literature Review #1

Beamer, E.M. and G.R. Pess. 1999. Effects of Peak Flows on Chinook (*Oncorhynchus tshawytscha*) Spawning Success in Two Puget Sound River Basins. *In* Proceedings: AWRA's 1999 Annual Water Resources Conference. Watershed Management to Protect Declining Species. Edited by R. Sakrison and P. Sturtevant.

Beamer and Pess investigated the relationship between peak flows during the egg incubation period for chinook and subsequent recruit-to-spawner ratio in the Stillaguamish and Skagit basins. The study concludes that:

- The relationship between egg-to-fry migrant survival and flood-recurrence interval is an exponential one. This means that survival is very sensitive to annual peak flow magnitude, and that changes in flood recurrence interval can pose substantial adverse consequences.
- For high-flow events with a 20-year recurrence interval or greater between 1974 and 1990, no wild chinook stocks in either basin "replaced themselves", i.e., none had a recruit/spawner ratio greater than 1.0.
- More importantly, "replacement failure" occurred >30% of the time as a whole, suggesting that much smaller high-flow events (e.g., 2-year events) may have deleterious consequences. There are of course many other contributing factors, such as harvest management.
- On the North Fork Stillaguamish, the flood recurrence interval has gotten substantially shorter for flows of a particular magnitude. In fact, the authors postulate that the egg-to-migrant-fry survival for the 2-year event during the last few decades (1972-1995) is approximately equal to the survival rate for the 20-year event in the 1928-49 period. If incubation survival is truly limiting production, then this suggests that recruitment failure will occur in at least one-half of all years. This is supported by the fact that NF Stillaguamish wild chinook have failed to replace themselves over 70% of the time since 1980.

<u>Notes and Comments:</u>

The study does not postulate a specific mechanism for the negative relationship between peak-flow and egg-to-fry migrant survival, but many are possible. These include egg scour, suffocation due to silt and others.

It is important to consider the high flow-survival relationship in the context of many other factors. For example, if flows during spawning season have been reduced due to anthropogenic influences, or if the extent of spawning habitat has been reduced due to siltation or other factors, then the spatial distribution of redds is likely to be more restricted compared to historical conditions, with a greater proportion located in mid-channel. This means that a higher proportion of redds will be vulnerable to the effects of anomalously high flows.

Also, as a result of harvest management practices and habitat conditions, the average sizes of chinook and other salmon have decreased substantially in the past several decades. This means that spawners are likely to construct shallower redds in smaller-sized substrate, increasing vulnerability to high flows.

While we can develop a relatively accurate estimate of high flow recurrence intervals for the 1 to 5-year interval or possibly the 10-year interval in some basins, one must keep in mind that we do not have very many data points for estimating longer-interval events. This means that inferences about the relationship between certain long-interval flow events and chinook survival should be made with caution. This is particularly important given the exponential shape of the relationship.

The apparent negative impact of high-frequency events (e.g., 2-year flood) is particularly worrisome. This suggests that vulnerability to high-flows has substantially increased over time, and may also point toward the likely relative importance of various mechanisms. For example, it seems unlikely that high-frequency events would precipitate substantial bed load movement and scour across the majority of spawning areas. This suggests that other factors, such as streambank erosion and subsequent siltation, as well as spawning habitat availability and distribution, may be more important as causal mechanisms.

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Summary Literature Review #2

Pess, G.R., B.D. Collins, M. Pollock, T.J. Beechie, A. Haas, and S. Grigsby. 1999. Historic and current factors that limit coho salmon (*Oncorhynchus kisutch*) production in the Stillaguamish River basin, Washington State: Implications for salmonid habitat protection and restoration. A report prepared for Snohomish County Department of Public Works and the Stillaguamish Tribe of Indians. 46 pp.

Pess et al identify current and historic factors limiting the production of coho in the basin. Key factors include:

- Loss of 67-91% of off-channel habitats, mostly due to channels being filled, cut off, straightened and diked.
- Pool habitat has decreased 18% in mainstem areas and 21% in tributaries, reducing juvenile rearing capacity. In low-gradient areas, pool density is positively correlated with LWD density.
- Winter rearing habitat (mostly beaver ponds) has decreased by two-thirds since 1933, while summer rearing habitat has decreased by one-third. While summer rearing habitat was likely a strong limiting factor historically, both winter and summer rearing may limit current production. The majority of rearing habitat losses is associated with loss of beaver ponds, side-channel sloughs and tributary habitats.
- In mainstem areas, channel straightening and diking are responsible for the majority of habitat losses. In tributaries, habitat degradation (e.g., loss of pools) and impassable culverts are the main culprits.
- Restoration efforts should focus on creating beaver pond habitat, reconnecting sloughs, and eliminating passage barriers. Restoring isolated or degraded mainstem sloughs can recapture large blocks of rearing habitat compared to smaller, tributary-based actions, but both categories of restoration activities are important.
- While tributary and mainstem habitat quantity increased somewhat due to fish passage facilities at Granite Falls, net productivity did not increase due to habitat degradation.
- Importantly, spawning habitat is NOT a limiting factor for coho in 98% of streams evaluated in the field. Percent spawnable area for surveyed streams <4% gradient in the basin ranged from 0.1-20%, with a mean of 4%. Summer rearing habitat can be fully seeded with the current amount of spawning habitat.

<u>Notes and comments:</u>

The majority of preferred coho habitat in the basin is within forested and agricultural lands (<4% gradient). Adult coho enter the basin in late summer and early fall, spawn between November and February, with fry emergence in March and April. Summer months are generally spent in areas of emergence. Juveniles migrate to winter rearing areas downstream during first high-flow events in the fall.

Considering the stated importance of beaver ponds, it should be noted that the methods for estimating current and historical beaver pond extent were starkly different. Current estimates were based on aerial photography (1991) with field verification; historical estimates were model-based, applying historic beaver-density estimates, trapping records and habitat potential (based on gradient, confinement and discharge).

Coho juvenile production estimates (in smolts/km) for mainstem and large-tributary areas suffer from a lack of data on coho utilization of these habitat types. The study applied values from a WDFW study on the Bogachiel River, as did a previous study on the Skagit. It should be noted that the Bogachiel study identified a very broad range (340-2734 smolts/km), while the Stillaguamish study applied a static 600 smolts/km estimate.

The relative contribution to smolt production of different habitat types has changed over time. Historically, summer production was driven by tributary and beaver pond habitat, with lesser contributions from sloughs and mainstem areas. Today, as beaver ponds and sloughs have drastically decreased, summer production is more dependent on tributaries and mainstem areas. Winter rearing was historically dominated by beaver ponds, accounting for roughly 65% of total rearing capacity. Today, with beaver ponds contributing <20% of total production, tributary and mainstem areas are contributing a higher percentage of total production. Importantly, of all the habitat types included in the study, winter beaver ponds are thought to have by far the highest productivity per unit area, roughly 50% higher than the next category – winter tributary pool.

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Summary Literature Review #3

Collins, B.D. 1997. Effects of land use on the Stillaguamish River, Washington ~1870 to ~1990: Implications for salmonid habitat and water quality and their restoration. Report to the Stillaguamish Tribe of Indians. 77 pages.

Collins describes the effects of land-use changes since the mid 1800's on the morphology and sediment load of the Stillaguamish River, with implications for salmon production and the identification of habitat restoration priorities. Key findings:

- Roughly 85% of the salt marsh that fringes the river's delta was eliminated between 1870 and 1968. Salt marshes are important for juvenile salmonids of several species, including chinook, chum and pink salmon.
- Massive, floating log raft jams were historically prevalent along the mainstem, providing habitat complexity and facilitating the development and perseverance of stable floodplain sloughs. Between 1888 and the turn of the century, most of these jams were removed as part of a federal program. During the same period, extensive logging operations had cleared mature conifers from the banks of the mainstem, both forks, as well as most key tributaries, thereby reducing future LWD recruitment.
- The mainstem, North Fork and South Fork have narrowed substantially since the 1930s, due to bank revetments, straightening and filling of side channels and sloughs.
- In steeper, headwater areas, logging operations (including road building) account for ¾ of all landslides. Riparian logging and landslides have caused widening and aggradation of many tributary streams. Individual, deep-seated landslide events (e.g., DeForest Creek, Hazel and Gold Basin slides) account for a very large proportion of total sediment input. Turbidity levels are persistently elevated throughout the system as a result of these large, persistent slides.
- Gravel has been mined from the mainstem at rates exceeding natural deposition. However, the effects of mining on habitat has not been intensively studied in the Stillaguamish Basin.
- Annual peak flows exhibit some decadal-scale, cyclical patterns. In addition, on the North Fork, peak flows have increased at an average, linear rate of approximately 200 cfs/year. Ten of the largest eleven peak flow events occurred in the 16 years between 1980 and 1995 (no data in study after 1995). A similar pattern – though not quite as dramatic – has been observed in some lower-elevation tributaries with sufficient gauge records (Pilchuck Creek and Jim Creek).
- In the North Fork and South Fork, the area of vegetated islands and bars has been substantially reduced (28% and 46%, respectively).

<u>Notes and comments:</u>

The mainstem Stillaguamish became shorter and narrower between 1933 and 1991. The average width of the active channel narrowed substantially, especially in upper reaches of the mainstem. The mainstem also became somewhat deeper (0.5-2.0 meters), but the data points used in the analysis were not consistent and may have been locally affected by multiple factors, such as channel revetments, riparian logging and gravel mining. The active channel in the North Fork and South Fork narrowed by 20 and 30 meters (roughly 25% and 33%) respectively, during the same period, while Deer Creek *widened* by roughly 20 meters (50%).

There are several possible reasons for channel narrowing, including loss of channel-altering log jams and reclamation of gravel bars. Alternatively, following the intense logging operations beginning in the 1860's, the channels may have been substantially wider in 1933 than their historical width, and later narrowing may represent a return to more typical widths.

Widening of tributary streams is strongly correlated with land slides and a history of riparian logging. Insufficient data were available to analyze habitat-effects of channel widening, such as reduced pool area or other indicators.

Two decade-scale episodes or “waves” of massive bedload movement occurred in the 1970’s and 1980’s, due to logging and the DeForest Creek landslide, respectively. The report cites other sources to suggest that chinook spawning and steelhead rearing were substantially affected, but no details are provided in this report.

Sediment fluxes vary seasonally. 83% of annual sediment transport occurs during the four months from November-February, which coincides with spawning and incubation for most salmonid species. Sediment loads have also increased in summer months, with suspended sediment concentrations increasing substantially in the North and South Forks in the last 25 years.

In sum, mainstem areas of both forks and the Stillaguamish proper are narrower, deeper, more sediment-laden and less complex as a result of land-use changes in the last 150 years. The loss of side channels and sloughs has dramatically reduced rearing habitat, as well as low-energy refuge areas during peak flow events. In sum, these areas likely feature higher velocity, greater depth and poorer substrate during the winter in particular. On the North Fork, these factors have been coupled with a persistent trend of increasing peak flows. All of these factors have combined to make mainstem areas less productive and hospitable, particularly in winter during incubation for all species and winter-rearing for coho and steelhead in particular. Given the increased relative importance of mainstem and large tributary habitats due to the loss of sloughs and beaver ponds (Pess et al, Lit. Review #2), the impacts to mainstem areas pose significant impacts to overall production.

Tributary areas are wider and likely shallower, less shaded, less complex, and highly susceptible to landslides as a result of riparian logging practices and forest roads. Tributaries are often utilized during the summer for rearing by coho and steelhead. However, high temperatures, high sediment loads, lack of pools and LWD combine to produce less-hospitable tributary summer-rearing habitat. Although spawning habitat is not thought to limit coho production (Pess et al, Lit. Review #2), episodic as well as chronic land-slides may have substantial adverse impacts on coho and other tributary-spawning species due to suffocation of redds by fine sediment.

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Summary Literature Review #4

Washington State Conservation Commission. 1999. Salmon habitat limiting factors final report. Water Resource Inventory Area 5, Stillaguamish Watershed. 83 pages.

Many of the topics covered in the Limiting Factors Analysis (LFA) have been covered by the other documents reviewed under this contract. This review will focus on issues not already covered in reviews 1-3, and on supplemental information and any discrepancies between source documents.

Key findings:

- Beaver pond habitat has been reduced by 81-98%, while wetland acreage has been reduced by 78%.
- Low flows are a problem in several parts of the basin from July through September. Known low flow problem areas include: the lower mainstem and estuary, Church Creek, North Fork (from Oso to Whitehorse), Pilchuck Creek, Harvey/Armstrong Creek, Tributary 30. Low flows during spawning have been associated with poor coho smolt production in Church Creek. Low flow impairment is evident in a much higher proportion of the watershed than high-flow impairment.
- The loss of wetlands combined with groundwater withdrawal likely exacerbate the low flow problem.
- The most significant water quality problems affecting salmonids in the basin include high temperature, low dissolved oxygen, fine sediment and total suspended solids. Temperature and DO are primarily an issue during the summer and early fall months. Non-point source pollution is also a major factor in the Stillaguamish, particularly in lower portions of the watershed, due to agriculture, sewage disposal, urban runoff and forest practices.
- Sub-basins within the area were ranked for protection using five habitat factors: the current condition of the riparian area, level of recent landslide activity, beaver habitat, wetland conditions, and fish production. Highest priority sub-watershed based on their protection ranking include Squire Creek, Harvey/Armstrong, Upper South Fork, and Lower Pilchuck.
- The LFA ranks the impact of various limiting factors on different life stages by species, including Spawning/Incubation, Rearing/Migration, and Adult Migration. For chinook, coho and steelhead, the Rearing/Migration life stage category is impacted most dramatically by multiple limiting factors compared to adult life stages. For pink and chum salmon – consistent with their life history pattern – Spawning/Incubation as well as Adult Migration are most starkly affected.

<u>Notes and comments:</u>

Low flow can cause a multitude of problems for salmonids at different life stages. Adult and juvenile salmon may suffer from physical stranding or migration blockages, summer rearing habitat may be reduced, the concentration of pollutants may be elevated, temperatures may reach critical levels, and salt-water intrusion may extend further upstream into the mainstem.

Water temperature increases as a result of riparian vegetation removal, water withdrawal, channel widening (due to excess sediment), and heat-generating bio-chemical reactions due to excessive nutrient levels. In a 1996 study in the Mainstem and North Fork (as well as associated tributaries), water temperatures exceeded the "preferred" range for salmonids (i.e., <13ºC) over 50% of the time at 6 out of 7 sites during the June-September period. Potentially lethal temperatures (i.e., >20ºC) were recorded for significant periods of time on the lower Mainstem (at I-5), mouth of Pilchuck Creek, as well as North Fork at Smokes Farm.

Annual peak flows are typically associated with rain-on-snow events at relatively low elevation. Roughly one third of the Stillaguamish basin is within the typical rain-on-snow zone. High flows may significantly impact the redds of late-fall spawning species (pink, chum, chinook), winter rearing of coho and steelhead, and may flush large wood out of smaller streams, as is reported to have occurred in Canyon Creek.

Riverine wetlands along the main channel North Fork between RM 20-36 offer the best opportunities for restoration to reduce sedimentation and flow attenuation. Other North Fork sub-basins, including Hazel, Squire and Fortson, also provide opportunities for restoration of partially degraded wetlands. Numerous wetlands in the lower South Fork and mainstem have been severely degraded by land-use impacts. In addition, many have been disconnected from the river by flood-protection projects. Some of these areas pose potential reconnection/restoration opportunities.